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Hedge fund replication using a strategy specific modeling approach

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HEDGE FUND REPLICATION USING A STRATEGY SPECIFIC MODELING APPROACH

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ABSTRACT

Institutional investors and wealthy individuals have in the past allocated a significant portion of their portfolios to hedge funds with the expectation of unconditional and uncorrelated returns to the market. However, the financial crisis of 2008 has heightened investor sensitivity to the high fees, illiquidity, and lockup periods typically associated with hedge funds. Hedge fund indexes showing excellent returns and low volatility contain funds that are closed to new investments, while the performance of investable funds have been shown to be inferior to their non-investable counterparts. The lack of transparency and extreme variation in the performance of hedge funds make the due diligence process critical in selecting the right fund. These challenges have motivated a search for an alternative to hedge funds. Recent research has established that a significant part of hedge fund returns can be replicated by portfolios constructed using liquid financial instruments. Hedge fund replication products, or clones, answer several challenges faced by hedge fund investors by providing daily liquidity, easy monitoring, and complete transparency at a significant cost advantage to hedge funds. This thesis examines the performance of clones constructed with factors selected based on the economic relevance to each hedge fund strategy by using both a passive model with constant portfolio weights, and an active model requiring monthly rebalancing of portfolio weights. These clones are further compared against the top performing hedge funds to analyze if the clones continue to deliver against a higher benchmark with regard to both risk and return.

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1. INTRODUCTION

Hedge funds have traditionally served exclusively to wealthy individuals and institutional investors with the promise of delivering uncorrelated returns, absolute positive returns irrespective of market direction, and protecting investor capital. However, the financial crisis of 2008 has forced many investors to take a more critical look at hedge funds. Hedge funds charge very high fees in terms of management and performance fees, often have lockup periods, and offer very little or no transparency. The opaque nature of the hedge fund industry also makes it challenging to select hedge funds to invest in. Fund-of-funds hedge funds have traditionally answered this due diligence requirement at the price of an additional layer of fees, however, fund-of-funds again differ in their ability to add value and selecting an appropriate fund-of-funds can be just as challenging. Hedge fund indexes showing excellent return and low volatility are constructed using funds that choose to voluntarily report their data and have several biases associated with them that overestimate their returns. These indexes are also not truly representable of the investable hedge fund universe as they also contain funds that are closed to new investments.

Hedge fund replication products, or clones, address several of the challenges faced by investors considering investments in hedge funds. Hedge fund clones offer daily liquidity, complete transparency, and scalability to large investments, and also provide investors with immediate exposure to a desired hedge fund strategy. Clones can be used in their portfolios in lieu of hedge funds or during the due diligence period until they find

a suitable hedge fund manager to invest in so as to not miss immediate opportunities. The cost advantage over hedge fund investing and ease of monitoring of clones have made them a practical substitute to hedge funds in the portfolios of institutional and sophisticated investors. These replication products also clear the accessibility hurdle to investors who fail to meet the accreditation and minimum investment requirements of hedge funds, thereby allowing even the average retail trader access to hedge fund like returns and diversification options.

Paper 1 presents the idea of using funds selected based on performance characteristics to model clones, offering clones that are targeted to capture those characteristics in their performance. A general set of factors representing basic sources of risk covering stocks, bonds, currency, credit, and commodities are used to construct the clones. Both fixed weight and rolling window models, each offering different benefits and serving different investor needs, are used in modeling the clones for each hedge fund strategy. The clones are constructed for three sets of data, including all the funds, the funds with top 50% Sharpe ratios, and the top 50% returns through the sample period.

Paper 2 goes beyond the standard five factors used in paper 1 and progresses to using factors that are specifically chosen according to the underlying hedge fund strategy. The performances of the clones from these factors are compared to the performance of the funds and the clones made from the five basic factors that are used in paper 1. The fixed weight and rolling window models are again used to develop the clones. The clones constructed from factors specific to each hedge fund are again compared against the top performing funds to analyze if these clones continue to deliver better performance against a higher benchmark.

This thesis examines the importance of selecting factors that are economically relevant to each hedge fund strategy and seeks to validate the well-established consensus that investors can obtain hedge fund like returns without the difficulties associated with investing in a standard hedge fund.

PAPER

I. Hedge Fund Replication using Liquid ETFs and Regression Analysis

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Abstract

Hedge fund replication involves the use of common factors or liquid Exchange Traded Funds (ETFs) in order to replicate the risk-return profile of common hedge fund strategies, including Convertible Arbitrage, Long/Short Equity, Global Marco, and Event Driven, among others. The benefits of replication are that traders and risk managers can replicate the risk-return profile of various hedge fund strategies or portfolios with increased transparency and lower costs, including lower management and performance fees. The added liquidity of ETFs also allow traders to avoid common hedge fund lock-up periods. To model various hedge fund strategies, the authors utilize historical hedge fund return data, along with regression analysis to model the returns of common trading and hedging strategies. Various input data selection procedures, such as those focusing on the best returns in each strategy category, or using the individual funds with the highest

Sharpe ratios, are also tested to determine their impact on the replication performance, as well as the risk-return flexibility of the replication modeling.

Keywords

Hedge Fund Replication, Exchange Traded Funds, Regression, Financial Risk and Return

1. Introduction

Hedge funds cater to wealthy, accredited investors. As a result, it is not uncommon for hedge funds to charge a management fee of 1-2% of assets, in addition to a performance fee of 10-20% [1]. In view of recent economic events, investors have grown increasingly nervous over these hefty fees along with other restrictions, such as lockup periods, lack of transparency, illiquidity and the extensive due diligence that are associated with hedge funds. Broad based hedge fund index replication products, such as the Goldman Sachs Absolute Return Tracker Index [2] and the Merrill Lynch Factor Index [3], are already being offered to institutional investors, with Credit Swiss now offering replicators for both the overall hedge fund industry and individual hedge fund strategies [4]. Imitation funds, such as Global X Guru Index and Alpha Clone Alternative Alpha that invest directly into long positions observed from the 13F filings of top fund managers, are also in existence. However, this group of replicators is secretive of their methods and typically charge high fees [5].

Investors have long tried to understand the source of returns of top performing investment institutions and managers, and have been ready to pay a premium for returns that outperform the market. Sharpe [6] provided a method to benchmark mutual fund performance and explains their return in terms of various asset classes. This paved the way to extend style analysis to hedge funds for estimating their risk exposures. Fung and Hsieh [7] used principle component analysis to group funds based on both their correlations with each other and their relation to various styles. Fung and Hsieh [8]

showed that trend following styles can be replicated to a fair degree by using look-back options.

A paper by Hasanhodzic and Lo [9] showed that for certain hedge fund categories it was possible to obtain comparable performance using a linear factor model that has a simple economic interpretation. This work will be the focus of our research as we use a similar factor model to test the performance of the clones using various strategies. One goal of the modeling is to maintain the simplicity of the linear factor model so as to be both attractive and accessible to a typical investor, while now allowing for added risk-return flexibility.

In the following sections we discuss our research methodology and then elaborate on the cloning techniques used in Hasanhodzic and Lo [9]. These techniques include fixed weight clones for a passive investor, along with a rolling window clone for an investor who prefers monthly rebalancing. We then use two techniques for satisfying different investor preferences. To obtain a more balanced risk-reward ratio, we use the funds with the highest Sharpe ratio in the cloning process. For those willing to take more risk, we focus on cloning the funds with the best returns. We discuss the impact of this selection process on the replication performance results and conclude with suggestions for further improvement and added flexibility in the clones.

2. Methodology

For our research methodology we use a sample of 1495 hedge funds with monthly returns from August 1996 to September 2008. The hedge funds are classified into eleven fund categories, including Event Driven, Long/Short Equity Hedge, Managed Futures, Global Macro, Fixed Income Arbitrage, Emerging Markets, Convertible Arbitrage, Dedicated Short-Bias, Multi-Strategy, Equity Market Neutral and Fund-of-Funds.

Hasanhodzic and Lo [9] showed that portfolios made up of common risk factors can provide comparable performance to a number of hedge fund categories and have the benefit of being transparent and easily traded through liquid instruments, such as Exchange Traded Funds (ETFs). The factors used by Hasanhodzic and Lo [9] include: 1) USD: U.S. Dollar Index Return; 2) SP500: S&P 500 Total Return; 3) Credit: the spread between the Lehman Corporate Bond Index and the Lehman Treasury Index; 4) Bond: Lehman Corporate AA Intermediate Bond Index; and 5) GSCI: Goldman Sachs Commodity Index Total Return. These factors are used to run a constrained regression on hedge funds in each fund category to obtain portfolio weights of the risk factors in the clones. Section 3 provides more details on the modeling approach used by Hasanhodzic and Lo [9] in constructing their fixed-weight and rolling window clones.

3. Initial Modeling and Results

3.1 Fixed-Weight Clones

To construct the fixed weight clones, we run a regression on the fund's returns (R_{it}) with the aforementioned five factors. During modeling, the regression coefficients are constrained to sum to one, while also dropping the intercept. Dropping the intercept

forces the least-squares algorithm to use the factor means to fit the mean return of the fund [9]. The beta coefficients can be interpreted as portfolio weights in the clone.

$$R_{it} = \beta_{i1}USD_t + \beta_{i2}Bond_t + \beta_{i3}Credit_t + \beta_{i4}SP500_t + \beta_{i5}GSCI_t + \varepsilon_{it,} \quad (1)$$

$$t = 1, 2 \ldots T, \text{ subject to } \beta_{i1} + \ldots + \beta_{i5} = 1$$

The estimated regression coefficients are used as the portfolio weights to give the portfolio returns (R^*_{it}), which are then renormalized to obtain the clone portfolio return (R_{it}^{clone}) that has the same sample volatility as the original fund [9].

$$R^*_{it} = \beta^*_{i1}USD_t + \beta^*_{i2}Bond_t + \beta^*_{i3}Credit_t + \beta^*_{i4}SP500_t + \beta^*_{i5}GSCI_t \quad (2)$$

$$R_{it}^{clone} = \gamma_i R^*_{it,} \qquad \gamma_i = \sigma_R / \sigma_{R^*} \quad (3)$$

The portfolio weights and renormalization factors of the fixed-weight clones stay constant over time for each clone. Table 1 presents a comparison of the performance of the fixed-weight clones, as well as the funds from which they are derived.

The average mean return of the clones are higher than that of the funds in the cases of Equity Market Neutral, Managed Futures and Global Macro. It must be noted that the clone portfolios are less expensive and are considerably more liquid than their fund counterparts, and hence deserve consideration even in categories where they slightly underperform.

Table 1: Comparison of all funds and their fixed weight clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Fixed Weight Funds							
Convertible Arbitrage	53	8.6386	3.7167	6.3012	4.7895	2.328	3.2404
Dedicated Short Bias	13	4.8201	5.4648	23.1809	8.6865	0.1837	0.2631
Emerging Markets	67	16.7964	7.9913	18.7842	11.8901	1.2251	0.9862
Equity Market Neutral	76	7.6546	4.3231	9.146	9.6008	1.4457	1.3988
Event Driven	59	10.6814	5.4156	8.5589	4.2339	1.4374	0.7565
Fixed Income Arbitrage	42	8.5226	2.792	6.6932	4.1345	2.1373	2.5498
Global Macro	62	13.3915	6.8244	15.0045	7.7812	0.9909	0.4618
Long/Short Equity Hedge	498	12.3541	6.6903	14.4087	7.9523	0.966	0.4416
Managed Futures	211	13.5724	7.6039	18.8518	10.2627	0.789	0.3774
Multi-Strategy	91	9.3471	5.7469	9.4222	7.3416	1.3492	0.8466
Fund-of-Funds	323	9.129	2.996	7.6545	4.839	1.4718	0.6511
Total	*1495*						
Fixed Weight Linear Clones							
Convertible Arbitrage	53	4.7008	3.2187	6.3012	4.7895	1.0261	0.455
Dedicated Short Bias	13	8.0536	9.2329	23.1809	8.6865	0.3734	0.3749
Emerging Markets	67	9.3651	4.9013	18.7842	11.8901	0.6733	0.4244
Equity Market Neutral	76	9.4393	10.406	9.146	9.6008	1.1232	0.3931
Event Driven	59	6.3965	3.0841	8.5589	4.2339	0.844	0.3597
Fixed Income Arbitrage	42	6.6233	3.4836	6.6932	4.1345	1.1654	0.447
Global Macro	62	13.8627	10.1455	15.0045	7.7812	0.9978	0.4821
Long/Short Equity Hedge	498	8.1456	6.8011	14.4087	7.9523	0.6458	0.4134
Managed Futures	211	22.1205	12.4523	18.8518	10.2627	1.2398	0.4036
Multi-Strategy	91	6.8146	7.9215	9.4222	7.3416	0.9307	0.5266
Fund-of-Funds	323	6.7619	3.2923	7.6545	4.839	1.0501	0.4075
Total	*1495*						

3.2 Rolling Window Clones

We apply a similar process to construct the rolling-window clones, but now a 24-month rolling window regression is used to estimate the portfolio weights of the risk factors, with rebalancing each month for every clone [9].

$$R_{it-k} = \beta_{it1}USD_{t-k} + \beta_{it2}Bond_{t-k} + \beta_{it3}Credit_{t-k} + \beta_{it4}SP500_{t-k} + \beta_{it5}GSCI_{t-k} + \varepsilon_{it-k,} \quad (4)$$

$$k = 1 \text{ to } 24, \text{ subject to } \beta_{it1} + \ldots + \beta_{it5} = 1$$

With the renormalization now computed within the rolling window, the volatility of each clone will no longer be the same as the corresponding fund. Nonetheless, as long as the volatiles of the funds do not drastically shift over time, the clones and funds will still have similar volatilities [9].

$$R^{*}_{it} = \beta^{*}_{it1}USD_t + \beta^{*}_{it2}Bond_t + \beta^{*}_{it3}Credit_t + \beta^{*}_{it4}SP500_t + \beta^{*}_{it5}GSCI_t \quad (5)$$

$$R_{it}^{clone} = \gamma_{it} R^{*}_{it,} \qquad \gamma_{it} = \frac{\sqrt{\sum_{k=1}^{24}(R_{it-k} - \mu_{Rit})^2}}{\sqrt{\sum_{k=1}^{24}(R^{*}_{it-k} - \mu_{R*it})^2}} \quad (6)$$

Table 2 contains a performance comparison of rolling window clones and funds from which they are derived.

Table 2: Comparison of all funds and their 24-month rolling window clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Rolling Window Funds							
Convertible Arbitrage	53	7.6507	3.9782	4.6442	4.3293	3.065	5.0339
Dedicated Short Bias	13	3.3783	5.3497	19.1765	8.6665	0.146	0.3303
Emerging Markets	67	16.1654	8.0069	14.2624	10.6382	1.6375	1.2125
Equity Market Neutral	76	6.1055	4.3357	6.3047	5.9482	1.8797	2.9815
Event Driven	59	9.6585	4.769	6.1441	3.5295	1.8072	0.858
Fixed Income Arbitrage	42	7.0253	2.2164	4.4676	3.0117	2.9832	4.4232
Global Macro	62	10.9135	5.3513	11.5579	6.1696	1.0883	0.5219
Long/Short Equity Hedge	498	10.7916	6.238	10.4254	6.5072	1.1911	0.5168
Managed Futures	211	10.7406	6.1403	15.2862	9.0307	0.8118	0.475
Multi-Strategy	91	8.3995	4.3511	6.2706	4.5067	1.6832	0.9916
Fund-of-Funds	323	8.8644	2.9278	6.2418	4.1473	1.7947	0.8362
Total	*1495*						
Rolling Window Linear Clones							
Convertible Arbitrage	53	2.4477	4.2366	5.6583	4.5354	0.5935	0.5825
Dedicated Short Bias	13	-1.0536	5.991	15.9331	6.4144	-0.1605	0.4692
Emerging Markets	67	9.5284	9.1957	14.642	8.8071	0.728	0.4031
Equity Market Neutral	76	4.1527	5.2352	7.201	6.5294	0.6519	0.5498
Event Driven	59	5.8614	4.5821	7.7538	4.3007	0.8631	0.5219
Fixed Income Arbitrage	42	3.04	3.4865	5.0277	3.4534	0.7925	0.4946
Global Macro	62	9.0461	10.9186	13.5485	7.5443	0.685	0.6525
Long/Short Equity Hedge	498	9.942	8.4005	12.4677	6.7452	0.8347	0.4738
Managed Futures	211	16.0113	13.3889	17.7766	10.7423	0.9203	0.4899
Multi-Strategy	91	4.0189	8.5099	8.3197	6.3314	0.7718	0.6655
Fund-of-Funds	323	5.1649	3.3946	5.8286	4.1919	0.9629	0.2869
Total	*1495*						

The rolling window clones offer comparable performance in the fund categories of Global Macro, Long/Short Equity Hedge and Managed Futures.

Our analysis was fairly consistent with the results obtained in Hasanhodzic and Lo [9], with exception in the category of Convertible Arbitrage. In section 4 we focus on

improving the performance and flexibility of the replicating model by using funds with higher performance in terms of Sharpe ratio and returns. We test to see if setting a higher benchmark for the replication procedure will continue to produce good clones, even though less data is used, and whether isolating risk and/or return can provide more options for individual investors.

4. New Data Selection and Results

We identified and tested two data selection strategies to improve the risk-to-return flexibility of the clones. By focusing on the funds with higher Sharpe ratios, we obtain clone portfolios with improved risk-to-return ratios as compared to clones from all the funds in each category. Likewise, replicating the funds with higher return results in clones with higher average returns. Although this approach uses less data and may involve accepting more risk, these clones should provide improved Sharpe ratios as compared to cloning all funds. For the modeling, we use the same fixed-weight and rolling window approach of Hasanhodzic and Lo [9], as highlighted in section 3.

4.1 The Top Sharpe Ratio Funds and Their Clones

Table 3 gives the performance comparison of the fixed weight funds with the highest Sharpe ratios, along with their clones. As expected, in comparing the results in Table 3 with Table 1, we see that on average the clones in Table 3 have higher Sharpe ratios across all fund categories, and in cases of Dedicated Short Bias (13.35% with clones of

selected funds vs. 8.05% with clones of all funds), Long/Short (9.26% with clones of selected funds vs. 8.15% with clones of all funds) and Emerging Markets (10% with clones of selected funds vs. 9.37% with clones of all funds), the clones also have higher expected returns. Of note is the significant reduction of standard-deviation in average expected returns of clones in the cases of Global Macro (6.3% with clones of selected funds vs. 10.14% with clones of all funds), Equity Market Neutral (3.3% with clones of selected funds vs. 10.41% with clones of all funds) and Multi-Strategy (4.18% with clones of selected funds vs. 7.92% with clones of all funds).

Table 3: Comparison of top 50% Sharpe ratio funds and their fixed-weight clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Fixed Weight Funds using the Top 50% Sharpe Ratios							
Convertible Arbitrage	26	9.5625	3.5997	4.1298	2.1341	3.6774	4.2419
Dedicated Short Bias	6	9.5046	3.9039	24.2565	8.161	0.4121	0.1469
Emerging Markets	33	17.9815	6.9874	13.0869	8.5666	1.8165	1.1225
Equity Market Neutral	38	8.8922	3.7544	4.9206	2.4066	2.3083	1.542
Event Driven	29	11.4844	5.5873	6.5063	3.5807	1.9462	0.7286
Fixed Income Arbitrage	21	8.9258	2.6578	3.7946	1.7327	3.3749	3.1704
Global Macro	31	15.5062	6.8798	12.1624	6.5032	1.3462	0.3656
Long/Short Equity Hedge	249	13.8479	6.8535	11.1263	5.704	1.296	0.3463
Managed Futures	105	15.1096	7.4624	15.6007	8.2941	1.0414	0.3662
Multi-Strategy	45	10.7685	4.7328	5.5951	2.7972	2.0296	0.5772
Fund-of-Funds	161	9.1174	2.6564	4.8578	1.8484	1.9809	0.5022
Total	*744*						
Fixed Weight Linear Clones with the Top 50% Sharpe Ratios							
Convertible Arbitrage	26	4.6769	2.0452	4.1298	2.1341	1.2509	0.3082
Dedicated Short Bias	6	13.3449	11.6547	24.2565	8.161	0.5965	0.4579
Emerging Markets	33	9.9984	4.6832	13.0869	8.5666	0.9522	0.4054
Equity Market Neutral	38	6.0046	3.2998	4.9206	2.4066	1.2558	0.3239

Table 3: Comparison of top 50% Sharpe ratio funds and their fixed-weight clones (cont.)

Event Driven	29	6.0871	2.6332	6.5063	3.5807	1.037	0.3429
Fixed Income Arbitrage	21	5.6505	2.9976	3.7946	1.7327	1.4688	0.2791
Global Macro	31	11.7792	6.3004	12.1624	6.5032	1.0176	0.374
Long/Short Equity Hedge	249	9.2642	6.9928	11.1263	5.704	0.8492	0.3628
Managed Futures	105	18.6596	11.3459	15.6007	8.2941	1.2719	0.4328
Multi -Strategy	45	6.4932	4.1814	5.5951	2.7972	1.1767	0.3128
Fund-of-Funds	161	6.2013	2.9396	4.8578	1.8484	1.2758	0.2604
Total	*744*						

Table 4 represents the rolling window clones with the same strategy of using the funds with the highest Sharpe ratios. Comparing Table 4 with Table 2 shows that this strategy improves the average Sharpe ratio of clones across all fund categories, and therefore can be used even with an active portfolio rebalancing approach to obtain a desired risk-to-reward ratio.

Table 4: Comparison of top 50% Sharpe ratio funds and their 24-month rolling window clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Rolling Window Funds using Top 50% Sharpe Ratios							
Convertible Arbitrage	26	8.2385	3.1204	3.0062	1.5436	4.9181	6.7423
Dedicated Short Bias	6	7.6179	4.8209	20.4851	8.052	0.3991	0.2751
Emerging Markets	33	15.6074	6.8253	8.8609	6.6448	2.3523	1.3586
Equity Market Neutral	38	7.2812	4.0085	3.4608	1.8132	3.0936	3.8545
Event Driven	29	9.9237	4.7103	4.6715	2.8791	2.3656	0.8355
Fixed Income Arbitrage	21	6.9905	2.0902	2.3775	1.1976	4.8203	5.7388
Global Macro	31	12.1548	5.7268	8.8463	5.1092	1.4771	0.427
Long/Short Equity Hedge	249	11.4931	6.5157	7.8833	4.6788	1.5402	0.4282
Managed Futures	105	11.839	5.8608	12.1286	7.1692	1.1036	0.5057
Multi-Strategy	45	9.4822	3.6039	4.1958	2.1025	2.4542	0.7842
Fund-of-Funds	161	8.8028	2.6448	3.9233	1.6305	2.423	0.6914
Total	*744*						

Table 4: Comparison of top 50% Sharpe ratio funds and their 24-month rolling window clones (cont.)

Rolling Window Linear Clones using the Top 50% Sharpe Ratios							
Convertible Arbitrage	26	3.3882	2.762	3.4932	1.935	0.9626	0.344
Dedicated Short Bias	6	0.5853	5.8714	15.9927	6.1591	-0.0045	0.4345
Emerging Markets	33	9.6637	11.7724	10.9442	8.9804	0.9067	0.4344
Equity Market Neutral	38	4.4249	3.7185	4.8375	3.1351	0.9091	0.344
Event Driven	29	5.6015	3.4671	6.0055	3.8815	0.9988	0.3946
Fixed Income Arbitrage	21	3.1678	2.5124	3.6848	2.8653	0.9242	0.39
Global Macro	31	10.9176	13.0015	11.8448	7.4104	0.8985	0.6637
Long/Short Equity Hedge	249	9.3169	5.9381	10.2498	5.3449	0.9456	0.406
Managed Futures	105	14.6192	10.4409	14.0522	8.1268	1.0538	0.5311
Multi-Strategy	45	4.6342	3.04	4.4381	2.1096	1.0525	0.407
Fund-of-Funds	161	4.2239	2.0846	3.9111	1.8051	1.0856	0.1953
Total	744						

Once again, and as expected, the clones in Tables 3 and 4 offer on average more attractive Sharpe ratios. Therefore, investors seeking a more balanced risk-to-reward ratio can benefit by using replicators that target funds with historically higher Sharpe ratios, rather than replicators that use a broad hedge fund replicator approach. Even though less data is utilized, acceptable replication performance is still achieved.

4.2 The Top Return Funds and Their Clones

We now use an approach similar to selecting the desired Sharpe ratio data, but instead select the funds with highest average returns, resulting in clones with significantly higher average return. By comparing the clones in Table 5 with Table 1, we note that as expected this selection strategy improves the performance of the clones in terms of average expected returns across all fund categories, even with less data available for

cloning. In several cases the average Sharpe ratio has also improved, such as for Emerging Markets (0.73 with clones of selected funds vs. 0.67 with clones of all funds), Equity Market Neutral (1.27 with clones of selected funds vs. 1.12 with clones of all funds), Fixed Income Arbitrage (1.27 with clones of selected funds vs. 1.17 with clones of all funds), Long/Short Equity Hedge (0.72 with clones of selected funds vs. 0.65 with clones of all funds) and Multi-Strategy (1.07 with clones of selected funds vs. 0.93 with clones of all funds).

Table 5: Comparison of top 50% average return funds and their fixed-weight clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Fixed Weight Funds using the Top 50% Average Returns							
Convertible Arbitrage	26	11.316	3.3154	7.9147	6.1984	2.7959	3.8328
Dedicated Short Bias	6	9.5046	3.9039	24.2565	8.161	0.4121	0.1469
Emerging Markets	33	22.5537	7.2929	22.9372	14.2013	1.4321	1.1232
Equity Market Neutral	38	10.5336	4.1885	10.3951	11.7694	1.6893	1.1723
Event Driven	29	14.9168	4.3047	10.4436	4.1972	1.5664	0.5115
Fixed Income Arbitrage	21	10.6681	2.2654	7.0426	4.7503	2.6522	3.018
Global Macro	31	18.2429	6.2664	18.5651	8.6461	1.1209	0.4683
Long/Short Equity Hedge	249	16.9964	6.2562	17.3597	8.771	1.1045	0.3926
Managed Futures	105	19.1808	6.7839	24.2593	10.9732	0.8921	0.3908
Multi-Strategy	45	13.5113	4.515	10.9939	8.8505	1.5867	0.7102
Fund-of-Funds	161	11.2613	2.6908	9.0994	5.1865	1.5212	0.6827
Total	*744*						
Fixed Weight Linear Clones of the Top 50% Average Returns							
Convertible Arbitrage	26	4.7041	4.3721	7.9147	6.1984	0.9639	0.5678
Dedicated Short Bias	6	13.3449	11.6547	24.2565	8.161	0.5965	0.4579
Emerging Markets	33	12.2406	4.7772	22.9372	14.2013	0.7332	0.4134
Equity Market Neutral	38	12.0896	13.4643	10.3951	11.7694	1.2727	0.3617
Event Driven	29	7.775	3.4856	10.4436	4.1972	0.8272	0.3905
Fixed Income Arbitrage	21	7.7895	3.9955	7.0426	4.7503	1.2716	0.4117
Global Macro	31	15.7173	12.5214	18.5651	8.6461	0.9122	0.4919

Table 5: Comparison of top 50% average return funds and their fixed-weight clones (cont.)

Long/Short Equity Hedge	249	10.8293	7.8843	17.3597	8.771	0.7167	0.4316
Managed Futures	105	27.0129	13.84	24.2593	10.9732	1.1715	0.4175
Multi-Strategy	45	9.3475	10.145	10.9939	8.8505	1.065	0.5004
Fund-of-Funds	161	8.0408	3.8367	9.0994	5.1865	1.0628	0.4669
Total	*744*						

Table 6 shows the results of the same selection technique now applied to a rolling window regression. A comparison of Table 6 with Table 2 shows the average return selection strategy to be effective in working with a monthly rebalancing approach that on average provides a higher expected return as compared to applying the rolling window cloning process to all funds.

With higher average returns across all fund categories, replication using the top return selection technique can be appealing to those investors targeting higher returns as compared to lower risk or higher risk-return ratios. Nonetheless, investors must be aware that this could also lead to investors taking on more risk as seen from the standard deviation of mean returns. However, the increased risk is justified across several fund categories as seen from their higher returns and improved Sharpe ratios.

Table 6: Comparison of top 50% average return funds and their 24-month rolling window clones

Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
		Mean	SD	Mean	SD	Mean	SD
Rolling Window Funds using the Top 50% Average Returns							
Convertible Arbitrage	26	10.5358	3.5836	6.2626	5.6932	3.708	5.8227
Dedicated Short Bias	6	7.6179	4.8209	20.4851	8.052	0.3991	0.2751

Table 6: Comparison of top 50% average return funds and their 24-month rolling window clones (cont.)

Emerging Markets	33	21.0865	8.3094	17.0337	12.9414	1.8964	1.3299
Equity Market Neutral	38	8.7284	4.406	6.9569	6.149	1.8554	1.1948
Event Driven	29	13.3725	3.8987	7.7341	3.9111	1.9434	0.5713
Fixed Income Arbitrage	21	8.4148	2.1475	4.8131	3.5657	3.3849	4.4743
Global Macro	31	14.0056	5.6653	13.7819	6.705	1.1754	0.5381
Long/Short Equity Hedge	249	14.4895	6.5001	12.7189	7.215	1.3086	0.5006
Managed Futures	105	15.0039	5.779	19.5865	9.9743	0.9117	0.5033
Multi-Strategy	45	11.4261	3.4736	7.6796	5.3226	1.8729	0.8487
Fund-of-Funds	161	10.9119	2.6058	7.4986	4.1708	1.7936	0.8558
Total	*744*						
Rolling Window Linear Clones using the Top 50% Average Returns							
Convertible Arbitrage	26	3.3065	5.5263	6.8687	5.9018	0.747	0.6278
Dedicated Short Bias	6	0.5853	5.8714	15.9927	6.1591	-0.0045	0.4345
Emerging Markets	33	11.2535	11.8288	17.1017	9.8944	0.7245	0.4799
Equity Market Neutral	38	5.0366	4.9142	6.8257	3.8261	0.7938	0.5212
Event Driven	29	7.7623	5.4124	8.5555	3.7559	0.9633	0.5821
Fixed Income Arbitrage	21	3.3557	4.3105	5.7327	3.7228	0.8062	0.5304
Global Macro	31	9.9069	13.6159	15.9702	8.8125	0.6415	0.6749
Long/Short Equity Hedge	249	11.7083	9.3141	14.0064	7.4869	0.8822	0.4229
Managed Futures	105	21.5489	15.507	22.7806	11.8043	0.9977	0.5061
Multi-Strategy	45	7.111	6.2565	8.3659	6.0355	0.9515	0.4563
Fund-of-Funds	161	6.211	3.9986	6.8757	4.1992	0.9674	0.2894
Total	*744*						

5. Conclusion

Our research has shown that the fund selection process has a significant impact of the performance of the clones. By setting a higher benchmark for the clones during replication, one can obtain better return performance, as expected, even though less data

is used during the replication process. Hence, it can be expected that clones based on strategies that choose funds with the highest Sharpe ratio, or funds with the highest average returns, can still provide similar replication performance even though less data is used as compared to replicating a larger and broader set of hedge funds. One potential drawback of this selection procedure is that at times it could be more difficult to match the higher benchmark during modeling. However, we believe that using factors that are more relevant to each strategy will yield better clone replications. Therefore, instead of always using the same ETFs during the replication process, no matter which strategy is being replicated, it may be possible to create better clones for each individual hedge fund strategy by choosing ETFs that provide more information content for the chosen strategy. This approach will be tested as a next step in an attempt to provide increased performance and replication, even when a smaller data set is provided or being modeled.

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II. Hedge Fund Replication using Strategy Specific Factors

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Abstract

Hedge funds have traditionally served wealthy individuals and institutional investors with the promise of delivering uncorrelated returns, absolute positive returns irrespective of market direction, and protecting investor capital. However, the financial crisis of 2008 has heightened investor sensitivity to the high fees, illiquidity, and lockup periods typically associated with hedge funds. The lack of transparency and extreme variation in

the performance of hedge funds make the due diligence process critical in selecting the right fund. In the crowded world of hedge funds, this can be expensive and time consuming. Hedge fund replication products, or clones, seek to answer these challenges faced by hedge fund investors by providing daily liquidity, complete transparency, and immediate exposure to a desired hedge fund strategy. Recent research has established that a significant part of hedge fund returns can be replicated by portfolios constructed using liquid tradable instruments. This paper examines the importance of constructing clones with factors selected based on the economic relevance to each hedge fund strategy, and then compares the clone performance against both the hedge funds and the clones constructed using a more general set of risk exposures. These clones are further compared against the top performing hedge funds to analyze if the clones continue to deliver against a higher benchmark with regard to both risk and return.

Keywords: Hedge Funds, Hedge Fund Replication, Regression, Hedge Fund Strategies

1. Introduction

Hedge fund replication products have received a lot of attention of late as an alternative to investing in hedge funds. Hedge funds have been pessimistic to regulation and disclosure as they fear that regulation can constraint their money making abilities and that full disclosure would lead to others copying their trades. Investors were happy with the elusive and non-transparent structure of hedge funds when they delivered double digit returns and low market correlation, however, the recent economic crisis has shown that hedge funds are not entirely immune to market events (Sourd 2009).

Hedge funds engage in techniques such as shorting to protect against adverse market returns and to maintain a lower correlation to the overall market. However, studies have shown that although they exhibit low correlation and superior returns during market uptrends, they tend to be severely affected during market downturns (Agarwal and Naik 2004). Investors are beginning to question the value they receive in exchange for paying the high fees charged by hedge funds, which have typically charged a management fee of around 1-2% of assets and an incentive-based performance fee of 15-20% (Fung and Hsieh 1999). They also have not traditionally gauged their performances against a benchmark, but increased investments from institutional investors seeking more accountability, and the lack of transparency has led these institutional investors to search for alternatives in the form of hedge fund replication products that offer complete transparency, along with daily liquidity that help avoid lock-up periods associated with hedge funds. Agarwal and Naik (2000) found that performance persistence decreases as

the return measurement period increases, and that persistence in losers is higher than among winners, making hedge fund selection important. Malkiel and Saha (2005) also showed a lack of persistence in the performance of hedge funds.

There is also evidence that the allure of hedge funds might be overstated. Hedge fund indexes showing stellar performance include funds that are closed to new investments, with the performance of investable funds having been found to be significantly inferior to the performance of the non-investable indexes (Feldman, et al. 2009). Choosing a hedge fund that is available to new investors in another challenge that needs extensive and expensive due diligence. This is somewhat addressed by investing in fund-of-funds hedge funds, which handle the due diligence and diversification process effectively, but this comes at the cost of an additional layer of fees. Research found that the average fund-of-funds hedge fund does not offer statistically significant alpha (Fung, et al. 2008), with any alpha delivered often consumed by fees (Fung and Hsieh 2007). A lack of consistency among hedge fund index providers also casts doubts over their usefulness; the heterogeneity across providers makes performance measurement of hedge fund categories difficult to analyze, and research has found convertible arbitrage to be the only truly homogenous category of hedge funds across hedge fund index providers (Kugler, et al. 2010). The effects of missing returns in hedge fund databases are often debated. However, Daniel, et al. (2012) showed that this isn't a serious concern as missing returns of liquidated funds are offset by successful funds that choose to stop reporting.

After Sharpe (1992) used an asset class factor model to decompose the performance of mutual funds, the focus shifted to hedge funds and substantial research has established

that a significant component of hedge fund returns are made up of systemic exposures that can be expressed in terms of liquid tradable instruments. Fung and Hsieh (2004) used a seven factor model that showed that up to 80% of the variance of returns of some broad hedge fund indexes can be explained by using a combination of equity and options based factors. Fung and Hsieh (2001) used look-back stradlles to replicate the returns of trend followers. Jaeger and Wagner (2005) used a multi-linear asset factor model that showed good results for strategies such as long/short and short bias, but performed poorly for complex strategies such as managed futures and equity market neutral. Li, et al. (2013) used factor models to highlight potential applications in hedging market exposure, for estimating daily VaR, and for forecasting the daily performance of hedge funds.

Within the last few years, researchers have also been replicating hedge fund returns (Hasanhodzic and Lo 2007; Kat and Palaro 2005), with hedge fund replication products, or clones, being a viable alternative to hedge funds for investors who are unable to meet the accreditation requirements needed to invest in hedge funds, and also to those investors challenged by the high minimum investments that hedge funds typically require. Institutional and sophisticated investors should consider hedge fund clones as they provide a significant cost advantage over hedge funds, offer daily liquidity, and are scalable to the capacity of investments that institutional investors can make. The clones also have an advantage in terms of complete transparency and ease of monitoring. The difficulty associated with selecting a hedge fund make clones an accessible choice that an investor can use to gain immediate exposure to the desired hedge fund strategy.

The replication attempts can be broadly classified into three categories: factor modeling, distribution replication, and rules-based replication. Distribution replication focuses the replication on the statistical properties of the hedge fund returns rather than tracking the monthly returns of the funds (Kat and Palaro 2005). This strategy is complex and can be difficult to implement, sometimes becoming more complicated than the underlying hedge fund trading strategies. Rules-based replication uses a set of defined trading rules to capture the core processes of specific hedge fund styles; a sub-category of this type of replication often used is mechanical replication. Mechanical replication seeks to mimic the holding of hedge funds, however, limitations in disclosures by hedge funds make this an ineffective strategy that suffers from lag even when copying the holdings revealed in the 13F filing of top managers. Factor based modeling offers a simple and easy to implement model that can be used to effectively replicate or clone various sub-styles of hedge funds. Hasanhodzic and Lo (2007) showed that by using a simple factor model made up of easily tradable factors, replications of funds can be achieved to a great extent.

This paper extends the analysis to cover individual hedge fund strategies by focusing on the importance of selecting the factor exposures that are economically relevant to each fund strategy. The performance of the replication models that obtain superior performance is also validated against a selection of top returning and top risk-adjusted returning funds.

2. Methodology

2.1. Initial motivation

Hasanhodzic and Lo (2007) showed that it is possible to construct clone portfolios that offer comparable performance to a number of hedge fund categories by using a basket of common and diverse risk factors that are easily tradable through liquid financial instruments. The hedge fund clones were constructed by regressing the individual hedge fund returns against five factors: 1) U.S. Dollar Index Return; 2) S&P 500 Total Return; 3) Spread between the Lehman Corporate Bond Index and the Lehman Treasury Index; 4) Lehman Corporate AA Intermediate Bond Index; and 5) Goldman Sachs Commodity Index Total Return. Each clone is a portfolio of the factors and these factors are used to run a constrained regression on hedge funds in each fund category to obtain portfolio weights of the risk factors in the clones. Two models are presented in the form of a fixed weight model (where the portfolio weights of the factors remain constant) and a rolling window model (where portfolio weights are rebalanced monthly). Hasanhodzic and Lo (2007) found that while the fixed weight clones performed well for a number of hedge fund strategies, the performance of the rolling window model was not quite as good. The fixed weight and rolling window models are outlined below.

Fixed weight model

The fixed weight model is constructed using an ordinary least squares algorithm with the regression coefficients constrained to sum to one. Dropping the intercept forces the least square algorithm to use the factors to fit the means returns of the fund, thereby giving an

optimized portfolio where the beta coefficients are interpreted as the factor weights in the clone for each respective fund.

$$R_{it} = \beta_{i1}F_{1t} + \beta_{i2}F_{2t} + \ldots + \beta_{in}F_{nt} + \varepsilon_{it}, \quad (1)$$

$$t = 1, 2 \ldots T$$

$$subject\ to\ \beta_{i1} + \ldots + \beta_{in} = 1$$

The estimated regression coefficients are used as the portfolio weights to give the portfolio returns $\{R^{*}_{it}\}$. $\{R^{*}_{it}\}$ is then renormalized to obtain the clone portfolio return, $\{R_{it}^{clone}\}$.

$$R^{*}_{it} = \beta^{*}_{i1}F_{1t} + \beta^{*}_{i2}F_{2t} + \ldots + \beta^{*}_{in}F_{nt} \quad (2)$$

$$R_{it}^{clone} = \gamma_i R^{*}_{it}, \qquad \gamma_i = \sigma_R / \sigma_{R^{*}} \quad (3)$$

The portfolio weights and renormalization factors of the fixed-weight clones stay constant over time for each clone.

Rolling window model

The rolling window model uses a 24-month rolling window regression to estimate the portfolio weights of the risk factors. This is a more dynamic model compared to the fixed weight model and can be seen as suitable for investors who want to actively rebalance their portfolios to capture the non-stationary nature in the hedge fund return series (Hasanhodzic and Lo 2007).

$$R_{it-k} = \beta_{it1}F_{1t-k} + \beta_{it2}F_{2t-k} + \ldots. + \beta_{itn}F_{nt-k} + \varepsilon_{it-k} \quad (4)$$

$$k = 1, 2 \ldots 24$$

$$subject\ to\ \beta_{it1}+\ldots.+\beta_{it\mathrm{n}}=1$$

Rebalancing is now done each month for every clone.

$$R^{*}_{it}=\beta^{*}_{it1}F_{1t}+\beta^{*}_{it2}F_{2t}+\ldots+\beta^{*}_{itn}F_{nt} \tag{5}$$

$$\mathrm{R}_{\mathrm{it}}^{\mathrm{clone}}=\gamma_{\mathrm{it}}\,\mathrm{R}^{*}_{\mathrm{it}},\quad \gamma_{\mathrm{it}}=\frac{\sqrt{\sum_{k=1}^{24}(R_{it-k}-\mu_{Rit})^{2}}}{\sqrt{\sum_{k=1}^{24}(R^{*}_{it-k}-\mu_{R*it})^{2}}} \tag{6}$$

2.2. Modeling approach

Fixed-weight and rolling-window models similar to the ones used by Hasanhodzic and Lo (2007) are used to analyze a sample of 1495 hedge funds with monthly returns from August 1996 to September 2008. The rolling window model requires the calibration of the 24-month rolling window regression and renormalization factor, and hence has the first 47 months excluded from the performance comparison of the funds and clones. However, all 145 months are used for analyzing the fixed-weight model. The sample includes funds belonging to various categories, such as convertible arbitrage, dedicated short bias, emerging markets, equity market neutral, event driven, fixed income arbitrage, long/short equity, global macro, managed futures, multi-strategy, and fund-of-funds. For each strategy, the factors used in the model are selected based on the characteristics of the underlying hedge fund category. The performance of the clones developed using these factors are compared to the funds and the clones constructed from the factors listed in section 2.

Three data selection procedures are used in the construction of the hedge fund clones that will give investors a more customizable clone model that offers the choice between the clones constructed using all funds, funds with higher Sharpe ratios, and funds with higher average returns. The performance of the clones constructed from factors specific to each hedge fund are again compared against those of the top performing funds to analyze if these clones continue to deliver better performance against a higher benchmark. Throughout the remainder of the paper, clone2 stands for the clones constructed from the factors considered specifically for each individual hedge fund category, while clone1 represents the clones that used the general set of factors listed in section 2, and previously used by Hasanhodzic and Lo (2007).

3. Strategy Overview

This section provides an overview of each hedge fund strategy and lists the factors used to construct clone2 under each category. The factors used to model clone2 are selected specifically for each hedge fund strategy.

3.1. Convertible Arbitrage

The convertible arbitrage category of hedge funds is a relative value strategy focused on capturing inefficiencies in the convertible bond market. Around $40 billion was under management in convertible arbitrage funds as of 2010, returning an average of 9.3%

annualized with a volatility of 7.7% between 1994 and 2010 (Credit Suisse 2011). A strategy utilized by these funds involves going long a convertible bond and taking a short position in the underlying stock. The hedge can also be in the form of credit default swaps, as well as interest rate and volatility derivatives. However, hedging only equity risk is more characteristic of convertible arbitrage hedge funds (Agarwal, et al. 2011).

The convertible bond market is very illiquid and the majority of the positions are held by convertible arbitrage funds. Although this illiquidity is often the source of their returns, it can quickly squeeze the funds into liquidating the bonds at losses during a credit crunch. The factors used to form the clones are selected with the goal of maintaining an overall consistency with the investment objectives of the respective hedge funds.

The factors selected to form the convertible arbitrage clone include the following:

1) Large Cap US Stocks: S&P 500 Total Return.
2) Bond: Lehman Corporate AA Intermediate Bond Index.
3) High Yield Bond: Merrill Lynch High Yield Master 2 Index.

3.2. Dedicated Short Bias

Dedicated short bias funds take both long and short exposures to equities while maintaining a net short position. This category performs well when the markets are in a

down-trend, but suffers in bull markets. Managers change their net short exposure according to their outlook on the overall market.

The factors used to replicate this strategy include the following:

1) Large Cap US Stocks: S&P 500 Total Return.
2) Small Cap US Stocks: Russell 2000 Small-Cap Index.
3) Treasury Rates: Lehman Treasury Index.

3.3. Emerging Market

Emerging market hedge funds seek to exploit opportunities developed by political, currency, credit, and interest rate uncertainties that occur in emerging markets, while also investing in their corresponding equity markets. These opportunities are also used by global macro and event driven hedge funds.

The factors used to develop emerging market clones include the following:

1) Emerging Market: MSCI Emerging Market Index.
2) High Yield Bond: Merrill Lynch High Yield Master 2 Index.
3) Bond: Lehman Corporate AA Intermediate Bond Index.
4) Currency: U.S. Dollar Index Return.

5) Credit Spreads: The spread between the Lehman Corporate Bond Index and the Lehman Treasury Index.

3.4. Equity Market Neutral

Equity Market Neutral (EMN) hedge funds aim to exploit certain opportunities presented by a specific group of stocks while staying neutral to the broad market. This strategy sometimes overlaps with relative value and long/short equity. It performed relatively well, losing fewer than 3% on average in 2008 and had the lowest volatility in a ten-year window between July 1999 and June 2009 (Low 2009). Equity market neutral managers perform frequent to moderate rebalancing of their portfolio to maintain market neutrality.

Although they are broadly market-neutral, EMN funds have exposures to a wide range of equity classes. Value and momentum factors perform well in different market environments and hence offer a balance to the portfolio. EMN funds also have exposures to the US and emerging market equities, and high yield bonds (Feldman, et al. 2009).

The factors used to construct the EMN clone include the following:

1) Market Momentum: MSCI USA Momentum Index.
2) Large Cap US Stocks: S&P 500 Total Return.
3) Value Stocks: MSCI USA Value Index.

4) Emerging Market: MSCI Emerging Market Index.

5) High Yield Bond: Merrill Lynch High Yield Master 2 Index.

6) Bond: Lehman Corporate AA Intermediate Bond Index.

3.5. Event Driven

The event driven category of hedge funds capitalizes on opportunities that develop in the short-term, causing mispricing in equities, bonds, and global markets. Key events can include mergers, acquisitions, and corporate restructuring. Event driven hedge funds perform poorly during down trending markets as deals are more likely to fall through during those times (Agarwal and Naik 2004).

The factors used to replicate the event driven strategy include:

1) High Yield Bond: Merrill Lynch High Yield Master 2 Index.

2) Emerging Market: MSCI Emerging Market Index.

3) Value Stocks: MSCI USA Value Index.

4) Small Cap US Stocks: Russell 2000 Small-Cap Index.

3.6. Fixed Income Arbitrage

Fixed Income arbitrage is another relative value strategy used to exploit bond market inefficiencies. As of 2010, these funds have about $120 billion worth of assets under management and have delivered an average of 5.3% annualized return with 6% volatility between 1994 and 2010 (Credit Suisse 2011). This strategy performs well in a low volatility environment. However, it is particularly susceptible to crowed trades and needs to take on very high leverage to deliver substantial returns. The strategy typically profits by holding long positions in higher yielding bonds and short positions in lower yielding bonds. This strategy is known to have exposure to fixed income spreads, and though a number of spread combinations can be chosen as a factor, the credit spread is the best option because of its' long history and how widening credit spreads usually result in other spreads also widening (Fung and Hsieh 2002) .

The Long-Term Capital Management story stands out to underscoring the risks prevalent with fixed income arbitrage trades as crowding out the yield spread trade can cause the spreads to narrow, thereby limiting the possible return, causing the funds to take on more risk with higher leverage and potential margin calls (Jorion 2000).

The factors selected to form the fixed income arbitrage clone include the following:

1) Credit Spreads: the spread between the Lehman Corporate Bond Index and the Lehman Treasury Index.

2) Large Cap US Stocks: S&P 500 Total Return.

3) Bond: Lehman Corporate AA Intermediate Bond Index.

4) High Yield Bond: Merrill Lynch High Yield Master 2 Index.

3.7. Global Macro

The global macro hedge fund is a category that especially appeals to institutional investors due to its liquidity. Global macro is one of the few hedge fund strategies that lost fewer than 5% in 2008 when most hedge fund strategies had double-digit percentage losses (Low 2009). Its robustness can be seen in its performance between 2000 and 2010 where it returned an average of near 12% annualized return with a volatility of 5.5%, illustrating how the strategies of global macro funds perform well in volatile market environments, with about $290 billion under management (Casano 2010). The global macro strategy invests in a very broad range of asset classes and geographies.

The factors used to construct the clones of global macro include the following:

1) Bond: Lehman Corporate AA Intermediate Bond Index.
2) Large Cap US Stocks: S&P 500 Total Return.
3) Emerging Market: MSCI Emerging Market Index.
4) Currency: U.S. Dollar Index Return.
5) Commodity: Goldman Sachs Commodity Index Total Return.

3.8. Long/Short Equity

Long/Short hedge funds take both long and short positions in a broad range of equity classes spread across different size, style, and regions. These funds benefit from a positive equity environment and delivered an annualized return of 9.5% with 10.6% volatility between January 1998 and October 2009. This strategy will underperform long-only strategies during a strong bull market, however, the long-short strategy will outperform over a full market cycle (Bruce and Reynolds 2010) .

The long/short strategy has become the most established hedge fund strategy with over 30% of all the assets under management in hedge funds invested in long/short funds, comprising over 43% of all hedge funds (Feldman, et al. 2009). Although these funds are typically long biased, their strategies sometimes overlap those of equity market neutral funds in times of market downturns. The factors used to construct the clones for long/short equity hedge funds include a wide range of equity factors to which the funds usually have exposures.

The factors used to construct long/short clones include the following:

1) Large Cap US Stocks: S&P 500 Total Return.
2) Small Cap US Stocks: Russell 2000 Small Cap Index.
3) Developed International Markets: MSCI EAFE Index.
4) Market Momentum: MSCI USA Momentum Index.

5) Bond: Lehman Corporate AA Intermediate Bond Index.

3.9. Managed Futures

Managed futures hedge funds seek to capture returns by capitalizing on trends across a range of asset classes, including equities, commodities, fixed income, and currencies. Managed futures was the best performing hedge fund strategy in 2008, returning over 16% when most of the other strategies ended the year in negative territory and had over $330 billion in assets under management by the end of 2012 (Drachman 2013). The strategy also has a very low correlation to broad market indices and has returned over 8.6% annualized with 12.2% volatility between September 2000 and September 2010 (Casano 2010).

The flexibility of this strategy also results in high variation in the performance between different managers. The best performing managed futures fund in 2012 returned over 13%, while the worst performer lost over 27%, yet these funds have the ability to capture both uptrends and down trends and have a history performing well in either trend markets (Till and Eagleeye 2011). The managed futures strategy returned over 35% during the tech downturn between September 2000 and December 2002 and over 31% in the following market bull run ending in October 2007 (Drachman 2013).

The factors used to replicate the managed futures funds include the following:

1) Currency: U.S. Dollar Index Return.
2) Treasury Rates: Lehman Treasury Index.
3) Commodity: Goldman Sachs Commodity Index Total Return.
4) Large Cap US Stocks: S&P 500 Total Return.
5) Market Volatility: CBOE Volatility Index.

3.10. Multi-Strategy

Multi-Strategy hedge funds often develop from successful single strategy funds that extend their services to accommodate incoming capital when it reaches a capacity that managers see as the optimum threshold beyond which they believe that they will be inefficient in using fresh capital towards a single strategy. This category can be expected to offer diversification, higher capacity, and consistency in the long term.

The factors used to construct multi-strategy clones include the following:

1) Credit Spreads: The spread between the Lehman Corporate Bond Index and the Lehman Treasury Index.
2) Large Cap US Stocks: S&P 500 Total Return.
3) High Yield Bond: Merrill Lynch High Yield Master 2 Index.
4) Emerging Market: MSCI Emerging Market Index.

5) Bond: Lehman Corporate AA Intermediate Bond Index.

3.11. Fund-of-Funds

This fund-of-funds hedge fund category is used by investors who want to construct a portfolio of hedge funds in order to increase diversification and decrease correlation to the overall markets. Constructing a portfolio of hedge funds requires extensive due diligence and access to performance information that is not easily available. Fund-of-funds hedge funds take care of the due diligence, manager selection, and risk monitoring in exchange for an additional layer of fees, typically in the range of 10% asset management fees and 1% performance fees. Fund-of-funds hedge funds can vary from one another in terms of the weighting to different managers, liquidity, strategy exposures, and extent of rebalancing between the managers (Suppal and Garza 2012).

The factors selected to clone the fund-of-funds include the following:

1) Credit Spreads: The spread between the Lehman Corporate Bond Index and the Lehman Treasury Index.
2) Large Cap US Stocks: S&P 500 Total Return.
3) High Yield Bond: Merrill Lynch High Yield Master 2 Index.
4) Emerging Market: MSCI Emerging Market Index.
5) Bond: Lehman Corporate AA Intermediate Bond Index.

4. Results

This section discusses the results of the replication process using the fixed weight and rolling window clone models discussed in section 2, and then compares the benefits of selecting factors specific to the underlying hedge fund strategy versus simply using a broad set of factors covering basic sources of risk associated with stocks, bonds, currency, credit, and commodities. While the fixed weight model is suitable for investors wanting a more passive approach to using their hedge fund clones, the rolling window model is more for investors that prefer active monthly rebalancing.

Also covered in this section are the results of the clones constructed from the funds with the highest Sharpe ratios and the funds with the best average returns. The selection bias inherent in the cloning process is used to the benefit of the investors to allow for more customization of the clones and the ability to model them according to their preferences for risk and return. Investors prioritizing a more balanced risk-reward ratio can choose the clones constructed from the top Sharpe ratio funds, while investors seeking higher raw returns can use the clones constructed from the top returning funds.

4.1. All Funds

Table 1 shows the performance comparison for the clones created using all funds for the fixed weight model. The results for clone2 are impressive across several categories and

are significantly better than that of clone1 for all hedge fund strategies, with the exception of dedicated short bias and managed futures. Please note that one of the goals in selecting factors specific to the hedge fund strategy is to obtain clones with mean returns closer to that of the hedge funds. Therefore, in the case of managed futures, although clone1 has higher average mean return (22.12% clone1 vs. 15.37% clone2 vs. 13.57% funds), the performance of clone2 is preferable given that both its return is closer to the actual funds, and the standard deviation among mean returns is lower than clone1. In the case of dedicated short bias, although clone1 appears to have an average mean return closer to that of the fund, the higher standard deviation among mean returns, combined with the lower Sharpe ratio, makes clone2 the preferred choice. Equity market neutral provides for an interesting observation with clone2 providing much higher mean returns, but with comparable variance in mean returns. They also have very close Sharpe ratios (1.43 clone2 vs. 1.45 clone1).

The average mean return of clone2 is strikingly close to the average mean return of the funds in the case of convertible arbitrage (8.17% clone2 vs. 8.64% funds), emerging markets (17.04% clone2 vs. 16.80 funds), fixed income arbitrage (7.88% clone2 vs. 8.52% funds), long/short equity hedge (11.73% clone2 vs. 12.35% funds), and fund-of-funds (9.46% clone2 vs. 9.13% funds). The standard deviation among mean returns is also close in these cases. Multi-Strategy also offers clones with comparable mean returns and Sharpe ratio. The average Sharpe ratio of clone2 is higher than that of clone1 in all cases except managed futures, and is close to the mean Sharpe ratio of the funds for several categories. As illustrated by the results in Table 1, clone2 is the preferred over

clone1 for all hedge fund strategies when constructed using all funds, and provides notably close performance to the funds in most cases.

The rolling window comparison of the performance of both the clones and that of the corresponding funds for all the funds is provided in Table 2. These results show that clone2 remains the preferred choice among all hedge fund strategies.

Clone2 continues to offer highly comparable performance to the funds with the rolling window model having a few exceptions coming in the categories of event driven, fixed income arbitrage, and multi-strategy. Convertible arbitrage (10.11% clone2 vs. 8.91% funds) and global macro (14.83% clone2 vs. 13.05% funds) have higher average mean returns for the clone2 models, although the variance in mean returns is much higher for global macro clones2 (11.88% clone2 vs. 6.37% funds). However, the comparable Sharpe ratios (1.16 clone2 and 1.1 funds) make it a clone worth considering. Emerging markets and fund-of-funds categories have their clones2 perform close to the funds in terms of mean returns, while having slightly higher variance in mean returns. Long/short equity hedge and equity market neutral strategies have the clone2 models perform remarkably well, both in terms of their average mean returns and the variance in mean returns.

Table 1: Performance comparison for fixed weight model for all funds and their clones

Fixed Weight Model - All Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	53	8.64	3.72	6.30	4.79	2.33	3.24
Clone1	Convertible Arbitrage	53	4.70	3.22	6.30	4.79	1.03	0.46
Clone2	Convertible Arbitrage	53	8.17	3.06	6.30	4.79	1.55	0.38
Funds	Dedicated Short Bias	13	4.82	5.46	23.18	8.69	0.18	0.26
Clone1	Dedicated Short Bias	13	8.05	9.23	23.18	8.69	0.37	0.37
CLone2	Dedicated Short Bias	13	11.82	6.33	23.18	8.69	0.57	0.28
Funds	Emerging Markets	67	16.80	7.99	18.78	11.89	1.23	0.99
Clone1	Emerging Markets	67	9.37	4.90	18.78	11.89	0.67	0.42
CLone2	Emerging Markets	67	17.04	8.14	18.78	11.89	1.09	0.43
Funds	Equity Market Neutral	76	7.65	4.32	9.15	9.60	1.45	1.40
Clone1	Equity Market Neutral	76	9.44	10.41	9.15	9.60	1.12	0.39
CLone2	Equity Market Neutral	76	10.48	5.32	9.15	9.60	1.43	0.39
Funds	Event Driven	59	10.68	5.42	8.56	4.23	1.44	0.76
Clone1	Event Driven	59	6.40	3.08	8.56	4.23	0.84	0.36
CLone2	Event Driven	59	7.79	4.69	8.56	4.23	0.90	0.21
Funds	Fixed Income Arbitrage	42	8.52	2.79	6.69	4.13	2.14	2.55
Clone1	Fixed Income Arbitrage	42	6.62	3.48	6.69	4.13	1.17	0.45
CLone2	Fixed Income Arbitrage	42	7.88	4.14	6.69	4.13	1.31	0.36
Funds	Global Macro	62	13.39	6.82	15.00	7.78	0.99	0.46
Clone1	Global Macro	62	13.86	10.15	15.00	7.78	1.00	0.48
CLone2	Global Macro	62	16.88	8.02	15.00	7.78	1.24	0.43
Funds	Long/Short Equity Hedge	498	12.35	6.69	14.41	7.95	0.97	0.44
Clone1	Long/Short Equity Hedge	498	8.15	6.80	14.41	7.95	0.65	0.41
CLone2	Long/Short Equity Hedge	498	11.73	5.20	14.41	7.95	0.94	0.38
Funds	Managed Futures	211	13.57	7.60	18.85	10.26	0.79	0.38
Clone1	Managed Futures	211	22.12	12.45	18.85	10.26	1.24	0.40
CLone2	Managed Futures	211	15.37	8.98	18.85	10.26	0.84	0.26
Funds	Multi Strategy	91	9.35	5.75	9.42	7.34	1.35	0.85
Clone1	Multi Strategy	91	6.81	7.92	9.42	7.34	0.93	0.53
CLone2	Multi Strategy	91	10.42	8.99	9.42	7.34	1.25	0.55
Funds	Fund of Funds	323	9.13	3.00	7.65	4.84	1.47	0.65
Clone1	Fund of Funds	323	6.76	3.29	7.65	4.84	1.05	0.41
CLone2	Fund of Funds	323	9.46	4.26	7.65	4.84	1.37	0.33

Table 2: Performance comparison for rolling window model for all funds and their clones

Rolling Window Model - All Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	53	8.91	4.62	5.54	4.56	3.02	5.09
Clone1	Convertible Arbitrage	53	2.45	4.24	5.66	4.54	0.59	0.58
Clone2	Convertible Arbitrage	53	10.11	4.95	6.17	4.51	1.88	0.47
Funds	Dedicated Short Bias	13	3.37	4.84	18.98	8.31	0.17	0.39
Clone1	Dedicated Short Bias	13	-1.05	5.99	15.93	6.41	-0.16	0.47
CLone2	Dedicated Short Bias	13	7.58	3.57	14.92	5.77	0.58	0.30
Funds	Emerging Markets	67	21.50	10.60	15.43	9.80	1.77	1.15
Clone1	Emerging Markets	67	9.53	9.20	14.64	8.81	0.73	0.40
CLone2	Emerging Markets	67	19.69	13.36	14.56	8.97	1.40	0.35
Funds	Equity Market Neutral	76	7.16	5.20	7.66	7.14	1.75	2.46
Clone1	Equity Market Neutral	76	4.15	5.24	7.20	6.53	0.65	0.55
CLone2	Equity Market Neutral	76	7.69	5.55	7.41	7.30	1.18	0.47
Funds	Event Driven	59	11.48	5.72	7.11	3.41	1.81	0.90
Clone1	Event Driven	59	5.86	4.58	7.75	4.30	0.86	0.52
CLone2	Event Driven	59	7.63	5.80	7.59	4.48	1.10	0.46
Funds	Fixed Income Arbitrage	42	8.83	3.13	4.64	2.72	3.13	4.25
Clone1	Fixed Income Arbitrage	42	3.04	3.49	5.03	3.45	0.79	0.49
CLone2	Fixed Income Arbitrage	42	4.14	2.54	4.97	3.54	1.03	0.46
Funds	Global Macro	62	13.05	6.37	13.38	6.18	1.10	0.54
Clone1	Global Macro	62	9.05	10.92	13.55	7.54	0.69	0.65
CLone2	Global Macro	62	14.83	11.88	13.34	7.32	1.16	0.64
Funds	Long/Short Equity Hedge	498	12.90	7.63	12.24	6.74	1.19	0.54
Clone1	Long/Short Equity Hedge	498	9.94	8.40	12.47	6.75	0.83	0.47
CLone2	Long/Short Equity Hedge	498	11.21	6.72	11.92	6.71	1.05	0.48
Funds	Managed Futures	211	12.21	7.08	17.43	9.75	0.81	0.49
Clone1	Managed Futures	211	16.01	13.39	17.78	10.74	0.92	0.49
CLone2	Managed Futures	211	14.38	12.72	17.23	10.68	0.87	0.51
Funds	Multi Strategy	91	9.96	5.36	7.45	5.40	1.75	1.11
Clone1	Multi Strategy	91	4.02	8.51	8.32	6.33	0.77	0.67
CLone2	Multi Strategy	91	6.61	10.63	8.31	6.23	1.06	0.79
Funds	Fund of Funds	323	9.32	3.49	6.20	4.25	1.88	0.84
Clone1	Fund of Funds	323	5.16	3.39	5.83	4.19	0.96	0.29
CLone2	Fund of Funds	323	8.38	6.47	5.82	4.11	1.45	0.29

The results for rolling window and fixed weight clone2 models for all funds show that selecting the factors relevant to the underlying hedge fund strategy will offer significant benefits, both in terms of replication quality and overall performance of the clones. Next

we analyze the results of the clones using these models for the top funds in terms of both risk-reward and raw returns.

4.2. Top 50% Sharpe Ratios

In this section we look at the performance of clones constructed from the top 50% of the funds having the highest Sharpe ratios. The clones generated from these funds will benefit from the balanced risk reward properties of its corresponding funds. Although matching this higher benchmark is more difficult, using the relevant factors significantly improves the performance of the clones. Clone2 continues to outperform clone1 in terms of replication quality across all hedge fund strategies.

Table 3 offers the comparison of the fixed weight clones and the funds selected under this strategy. It can be seen that despite the challenges of a higher benchmark, clones2 still offers significantly comparable performance across many categories, including emerging markets (15.81% clone2 and 17.98% funds), equity market neutral (7.68% clone2 and 8.89% funds), long/short equity (11.54% clone2 and 13.85% funds), fund-of-funds (7.52% clone2 and 9.12% funds), multi-strategy (8.38% clone2 and 10.76% funds), managed futures (13.35% clone2 and 15.11% funds) and global macro (14.98% clone2 and 15.51% funds). There is also a similar variance in mean returns for clone2 and their corresponding funds for these strategies.

Table 3: Performance comparison for fixed weight model for top 50% Sharpe ratio funds and their clones

Fixed Weight Model - Top 50 % Sharpe Ratios Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	26	9.56	3.60	4.13	2.13	3.68	4.24
Clone1	Convertible Arbitrage	26	4.68	2.05	4.13	2.13	1.25	0.31
Clone2	Convertible Arbitrage	26	6.50	2.70	4.13	2.13	1.69	0.26
Funds	Dedicated Short Bias	6	9.50	3.90	24.26	8.16	0.41	0.15
Clone1	Dedicated Short Bias	6	13.34	11.65	24.26	8.16	0.60	0.46
CLone2	Dedicated Short Bias	6	13.82	8.45	24.26	8.16	0.62	0.33
Funds	Emerging Markets	33	17.98	6.99	13.09	8.57	1.82	1.12
Clone1	Emerging Markets	33	10.00	4.68	13.09	8.57	0.95	0.41
CLone2	Emerging Markets	33	15.81	8.00	13.09	8.57	1.38	0.37
Funds	Equity Market Neutral	38	8.89	3.75	4.92	2.41	2.31	1.54
Clone1	Equity Market Neutral	38	6.00	3.30	4.92	2.41	1.26	0.32
CLone2	Equity Market Neutral	38	7.68	3.49	4.92	2.41	1.63	0.28
Funds	Event Driven	29	11.48	5.59	6.51	3.58	1.95	0.73
Clone1	Event Driven	29	6.09	2.63	6.51	3.58	1.04	0.34
CLone2	Event Driven	29	7.78	3.26	6.51	3.58	1.31	0.30
Funds	Fixed Income Arbitrage	21	8.93	2.66	3.79	1.73	3.37	3.17
Clone1	Fixed Income Arbitrage	21	5.65	3.00	3.79	1.73	1.47	0.28
CLone2	Fixed Income Arbitrage	21	5.85	2.88	3.79	1.73	1.53	0.20
Funds	Global Macro	31	15.51	6.88	12.16	6.50	1.35	0.37
Clone1	Global Macro	31	11.78	6.30	12.16	6.50	1.02	0.37
CLone2	Global Macro	31	14.98	7.33	12.16	6.50	1.31	0.37
Funds	Long/Short Equity Hedge	249	13.85	6.85	11.13	5.70	1.30	0.35
Clone1	Long/Short Equity Hedge	249	9.26	6.99	11.13	5.70	0.85	0.36
CLone2	Long/Short Equity Hedge	249	11.54	4.94	11.13	5.70	1.13	0.31
Funds	Managed Futures	105	15.11	7.46	15.60	8.29	1.04	0.37
Clone1	Managed Futures	105	18.66	11.35	15.60	8.29	1.27	0.43
CLone2	Managed Futures	105	13.35	7.81	15.60	8.29	0.87	0.24
Funds	Multi Strategy	45	10.77	4.73	5.60	2.80	2.03	0.58
Clone1	Multi Strategy	45	6.49	4.18	5.60	2.80	1.18	0.31
CLone2	Multi Strategy	45	8.38	5.51	5.60	2.80	1.47	0.28
Funds	Fund of Funds	161	9.12	2.66	4.86	1.85	1.98	0.50
Clone1	Fund of Funds	161	6.20	2.94	4.86	1.85	1.28	0.26
CLone2	Fund of Funds	161	7.52	3.30	4.86	1.85	1.54	0.20

Fixed income arbitrage, event driven, and convertible arbitrage categories have the clones underperform their corresponding funds. These strategies largely gain from illiquidity

risk and have significant left tail exposure; the top Sharpe ratio criterion is therefore likely to select the funds with the most illiquid exposures, making them more challenging to replicate.

Table 4: Performance comparison for rolling window model for top 50% Sharpe ratio funds and their clones

Rolling Window Model - Top 50 % Sharpe Ratios Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	26	9.71	4.08	3.67	1.93	4.85	6.84
Clone1	Convertible Arbitrage	26	3.39	2.76	3.49	1.94	0.96	0.34
Clone2	Convertible Arbitrage	26	8.26	5.01	3.91	2.21	2.08	0.20
Funds	Dedicated Short Bias	6	7.13	4.01	18.93	8.65	0.45	0.39
Clone1	Dedicated Short Bias	6	0.59	5.87	15.99	6.16	0.00	0.43
CLone2	Dedicated Short Bias	6	8.88	4.53	15.20	5.46	0.68	0.40
Funds	Emerging Markets	33	20.38	9.20	11.01	8.13	2.40	1.34
Clone1	Emerging Markets	33	9.66	11.77	10.94	8.98	0.91	0.43
CLone2	Emerging Markets	33	17.68	15.98	11.11	9.32	1.59	0.36
Funds	Equity Market Neutral	38	8.61	3.86	4.33	2.19	2.87	3.08
Clone1	Equity Market Neutral	38	4.42	3.72	4.84	3.14	0.91	0.34
CLone2	Equity Market Neutral	38	5.58	3.87	4.77	3.08	1.22	0.42
Funds	Event Driven	29	11.90	5.69	5.49	2.88	2.37	0.90
Clone1	Event Driven	29	5.60	3.47	6.01	3.88	1.00	0.39
CLone2	Event Driven	29	6.64	4.08	5.73	3.61	1.22	0.41
Funds	Fixed Income Arbitrage	21	8.69	2.98	2.98	1.52	4.75	5.60
Clone1	Fixed Income Arbitrage	21	3.17	2.51	3.68	2.87	0.92	0.39
CLone2	Fixed Income Arbitrage	21	3.62	2.37	3.50	2.63	1.18	0.46
Funds	Global Macro	31	15.26	6.16	10.89	5.54	1.51	0.43
Clone1	Global Macro	31	10.92	13.00	11.84	7.41	0.90	0.66
CLone2	Global Macro	31	15.79	14.46	11.53	7.11	1.35	0.72
Funds	Long/Short Equity Hedge	249	14.03	7.53	9.47	4.78	1.54	0.44
Clone1	Long/Short Equity Hedge	249	9.32	5.94	10.25	5.34	0.95	0.41
CLone2	Long/Short Equity Hedge	249	10.11	5.03	9.77	5.28	1.15	0.47
Funds	Managed Futures	105	13.49	6.36	14.08	7.63	1.09	0.53
Clone1	Managed Futures	105	14.62	10.44	14.05	8.13	1.05	0.53
CLone2	Managed Futures	105	11.67	8.75	13.59	8.21	0.92	0.51
Funds	Multi Strategy	45	10.90	4.42	4.54	2.26	2.62	0.90
Clone1	Multi Strategy	45	4.63	3.04	4.44	2.11	1.05	0.41
CLone2	Multi Strategy	45	6.12	4.08	4.50	2.14	1.32	0.49
Funds	Fund of Funds	161	9.10	2.47	3.94	1.67	2.50	0.69
Clone1	Fund of Funds	161	4.22	2.08	3.91	1.81	1.09	0.20
CLone2	Fund of Funds	161	6.08	3.46	3.90	1.82	1.52	0.20

The rolling window results of the clones and the selected hedge funds are provided in Table 4. As seen in the table, clone2 outperforms clone1 in all hedge fund categories with the exception of managed futures, where clone2 still offers comparable performance to the funds. The most notable clone performances are for convertible arbitrage (8.26% clone2 vs. 9.71% funds), dedicated short bias (8.88% clone2 vs. 7.13% funds), and global macro (15.79% clone2 vs. 15.26% funds). While the standard deviation in mean returns are also close for convertible arbitrage and dedicated short bias, the standard deviation in mean returns for global macro clone2 is significantly higher than that for the funds. The comparable Sharpe ratios indicate that clone2 offers some benefits. Clone2 for the rest of the categories perform poorly in terms of mean returns, but the benefit of choosing the factors with consideration to the hedge fund strategy is clearly evident in the significantly higher average Sharpe ratios relative to clone1 across every strategy except managed futures.

4.3. Top 50% Returns

In this section we see the performance of clones constructed from the top 50% of funds with the best average returns. These clones are for investors who prioritize seeking higher returns and benefit from this focus in constructing the clones. Clone2 again outperforms clone1 in terms of replication quality for all strategies and in terms of average returns and Sharpe ratio for all categories except managed futures, but clone2 remains the preferred

clone model. The top 50% Sharpe ratio funds and top 50% return funds are the same for dedicated short bias category.

Table 5: Performance comparison for fixed weight model for top 50% return funds and their clones

Fixed Weight Model - Top 50 % Return Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	26	11.32	3.32	7.91	6.20	2.80	3.83
Clone1	Convertible Arbitrage	26	4.70	4.37	7.91	6.20	0.96	0.57
Clone2	Convertible Arbitrage	26	8.49	3.27	7.91	6.20	1.39	0.47
Funds	Dedicated Short Bias	6	9.50	3.90	24.26	8.16	0.41	0.15
Clone1	Dedicated Short Bias	6	13.34	11.65	24.26	8.16	0.60	0.46
CLone2	Dedicated Short Bias	6	13.82	8.45	24.26	8.16	0.62	0.33
Funds	Emerging Markets	33	22.55	7.29	22.94	14.20	1.43	1.12
Clone1	Emerging Markets	33	12.24	4.78	22.94	14.20	0.73	0.41
CLone2	Emerging Markets	33	21.41	8.96	22.94	14.20	1.14	0.42
Funds	Equity Market Neutral	38	10.53	4.19	10.40	11.77	1.69	1.17
Clone1	Equity Market Neutral	38	12.09	13.46	10.40	11.77	1.27	0.36
CLone2	Equity Market Neutral	38	11.11	5.79	10.40	11.77	1.39	0.44
Funds	Event Driven	29	14.92	4.30	10.44	4.20	1.57	0.51
Clone1	Event Driven	29	7.78	3.49	10.44	4.20	0.83	0.39
CLone2	Event Driven	29	9.66	4.44	10.44	4.20	0.93	0.23
Funds	Fixed Income Arbitrage	21	10.67	2.27	7.04	4.75	2.65	3.02
Clone1	Fixed Income Arbitrage	21	7.79	4.00	7.04	4.75	1.27	0.41
CLone2	Fixed Income Arbitrage	21	9.04	4.89	7.04	4.75	1.39	0.27
Funds	Global Macro	31	18.24	6.27	18.57	8.65	1.12	0.47
Clone1	Global Macro	31	15.72	12.52	18.57	8.65	0.91	0.49
CLone2	Global Macro	31	18.85	8.80	18.57	8.65	1.13	0.42
Funds	Long/Short Equity Hedge	249	17.00	6.26	17.36	8.77	1.10	0.39
Clone1	Long/Short Equity Hedge	249	10.83	7.88	17.36	8.77	0.72	0.43
CLone2	Long/Short Equity Hedge	249	13.67	5.82	17.36	8.77	0.88	0.35
Funds	Managed Futures	105	19.18	6.78	24.26	10.97	0.89	0.39
Clone1	Managed Futures	105	27.01	13.84	24.26	10.97	1.17	0.42
CLone2	Managed Futures	105	19.91	9.49	24.26	10.97	0.86	0.25
Funds	Multi Strategy	45	13.51	4.52	10.99	8.85	1.59	0.71
Clone1	Multi Strategy	45	9.35	10.15	10.99	8.85	1.07	0.50
CLone2	Multi Strategy	45	14.67	9.58	10.99	8.85	1.44	0.38
Funds	Fund of Funds	161	11.26	2.69	9.10	5.19	1.52	0.68
Clone1	Fund of Funds	161	8.04	3.84	9.10	5.19	1.06	0.47
CLone2	Fund of Funds	161	11.31	4.56	9.10	5.19	1.38	0.38

The fixed weight model performance for the clones and funds that are selected using the higher returns strategy are provided in Table 5. Extremely good clones are obtained for emerging markets (21.41% clone2 vs. 22.55% funds) and equity market neutral (11.11% clone2 vs.10.53% funds) given their close variation in mean returns. Global macro and managed futures categories give performance very close to their respective funds for clone2 in terms of both average mean returns and Sharpe ratios. Fixed income arbitrage (9.04% clone2 vs. 10.67% funds), multi-strategy (14.67% clone2 vs. 13.51% funds), and fund-of-funds (11.31% clone2 vs. 11.26% funds) also exhibit good replication results. Long/short equity, event driven, convertible arbitrage, and dedicate short bias had poor replication performance, but the value of using the strategy specific factors can clearly be seen both in terms of average mean returns and Sharpe ratios relative to clone1.

Table 6 presents the performance results for the rolling window model for the clones and funds selected for the higher return strategy. Clone2 again provides a better replication performance relative to clone1 across all hedge fund categories and has better overall performance in terms of average returns and Sharpe ratio for all fund strategies except managed futures. As before for managed futures, clone2 is still preferred to clone1. Event driven is the worst performing clone2 in terms of difference in average mean returns (9.39% clone2 vs. 15.98% funds). This is the only category that performed poorly on all clone2 models. Fixed income arbitrage clone2 also performed poorly (4.5% clone2 vs. 10.72% funds). In general, this category also performed poorly for the other rolling window data selection strategies tested. Fung and Hsieh (2002) demonstrated that fixed income arbitrage funds have primarily static exposures and the nature of fixed income

arbitrage funds may cause it to perform poorly when used to model rolling window clones where the portfolio weights in a clone are rebalanced each month.

Table 6: Performance comparison for rolling window model for top 50% return funds and their clones

Rolling Window Model - Top 50 % Return Funds								
	Categories	Sample Size	Annual Mean Return %		Annual SD %		Annual Sharpe	
			Mean	SD	Mean	SD	Mean	SD
Funds	Convertible Arbitrage	26	12.10	4.47	7.14	5.96	3.71	5.91
Clone1	Convertible Arbitrage	26	3.31	5.53	6.87	5.90	0.75	0.63
Clone2	Convertible Arbitrage	26	10.51	5.65	7.32	5.69	1.77	0.60
Funds	Dedicated Short Bias	6	7.13	4.01	18.93	8.65	0.45	0.39
Clone1	Dedicated Short Bias	6	0.59	5.87	15.99	6.16	0.00	0.43
CLone2	Dedicated Short Bias	6	8.88	4.53	15.20	5.46	0.68	0.40
Funds	Emerging Markets	33	27.85	10.74	18.73	11.68	2.01	1.27
Clone1	Emerging Markets	33	11.25	11.83	17.10	9.89	0.72	0.48
CLone2	Emerging Markets	33	24.31	15.91	17.16	10.25	1.45	0.38
Funds	Equity Market Neutral	38	10.13	5.32	8.26	7.37	1.81	1.15
Clone1	Equity Market Neutral	38	5.04	4.91	6.83	3.83	0.79	0.52
CLone2	Equity Market Neutral	38	7.29	5.11	6.91	3.99	1.09	0.42
Funds	Event Driven	29	15.98	4.59	8.65	3.18	1.98	0.56
Clone1	Event Driven	29	7.76	5.41	8.56	3.76	0.96	0.58
CLone2	Event Driven	29	9.39	4.08	8.53	3.83	1.18	0.38
Funds	Fixed Income Arbitrage	21	10.72	3.07	5.33	3.36	3.49	4.44
Clone1	Fixed Income Arbitrage	21	3.36	4.31	5.73	3.72	0.81	0.53
CLone2	Fixed Income Arbitrage	21	4.51	2.29	5.63	3.96	1.03	0.45
Funds	Global Macro	31	17.05	6.36	16.15	6.45	1.19	0.54
Clone1	Global Macro	31	9.91	13.62	15.97	8.81	0.64	0.67
CLone2	Global Macro	31	16.70	15.13	15.75	8.50	1.08	0.67
Funds	Long/Short Equity Hedge	249	16.91	8.37	14.57	7.48	1.30	0.52
Clone1	Long/Short Equity Hedge	249	11.71	9.31	14.01	7.49	0.88	0.42
CLone2	Long/Short Equity Hedge	249	12.36	6.98	13.64	7.35	1.02	0.44
Funds	Managed Futures	105	17.15	6.61	22.20	10.57	0.91	0.51
Clone1	Managed Futures	105	21.55	15.51	22.78	11.80	1.00	0.51
CLone2	Managed Futures	105	18.51	14.89	22.32	11.86	0.87	0.49
Funds	Multi Strategy	45	13.58	4.60	8.94	6.30	1.97	0.97
Clone1	Multi Strategy	45	7.11	6.26	8.37	6.04	0.95	0.46
CLone2	Multi Strategy	45	10.59	6.80	8.37	6.05	1.37	0.45
Funds	Fund of Funds	161	11.28	3.61	7.51	4.55	1.85	0.83
Clone1	Fund of Funds	161	6.21	4.00	6.88	4.20	0.97	0.29
CLone2	Fund of Funds	161	10.29	7.03	6.92	4.14	1.49	0.31

Good clone performance can be seen for convertible arbitrage (10.51% clone2 vs. 12.1% funds) and dedicated short bias (8.88% clone2 vs. 7.13% funds) where the standard deviation in mean returns is also comparable. Global macro (16.7% clone2 vs. 17.05% funds), managed futures (18.51% clone2 vs. 17.15% funds), and fund-of-funds (10.29% clone2 vs. 11.28 funds) have comparable performance in terms of average mean returns, but have much larger variation in mean returns compared to their respective funds. The other strategies offered fairly comparable performance, with the benefits of selecting the factors based on the underlying hedge fund strategy once again clearly evident across all hedge fund strategies.

5. Conclusion

This research demonstrates that selecting factors specific to the underlying hedge fund strategy has significant advantages over those constructed using a general broad set of factors for each strategy. Clone2, which used strategy-specific factors, outperformed clone1 in almost every case, and usually by a significant margin, in terms of replication performance and risk-reward ratio. Using different fund selection strategies provides investors with additional options for their hedge fund replication products.

The clones constructed using all the funds exhibited excellent replication for both the fixed and rolling window models with only a few exceptions. The benefits of selecting the factors in accordance to the hedge fund strategy were also visibly evident across all

strategies. The top 50% Sharpe ratio funds selection strategy resulted in strong replication performance for most categories, barring fixed income arbitrage, event driven, and dedicated short bias for the fixed weight model. The rolling window model offered good replication for dedicated short bias, convertible arbitrage, managed futures, and global macro strategies. While the clone performed poorly for the other categories, there was a significant performance over the general clone1 model. The top 50% return funds selection strategy yielded clones that offered attractive replication performance for several strategies except in cases of long/short equity hedge, convertible arbitrage, event driven, and dedicate short bias for the fixed model. The rolling window model offered good clones for convertible arbitrage, dedicated short bias, global macro, managed futures, and fund-of-funds strategies. The difference in performance of hedge funds over the three fund selection procedures highlights the difficulty and importance of selecting hedge funds suitable to an investor's preference. While there is also a difference in the performance of the clones constructed by the three clone procedures, the expense and complexity in choosing and investing in a normal hedge fund makes the clones a more favorable choice.

It is also important to recognize that costs associated with rebalancing, leveraging, and transaction costs must be considered before choosing and implementing the clones. Another point to note is that hedge funds are capable of deviating from their stated styles, and more complicated models may be needed to account for these style drifts. This is not visible when a large number of funds are averaged together, as seen in the excellent performance of clones constructed from using all funds. However, by reducing the

number of funds considered in forming the clones, the style drift may become more apparent and difficult to capture for certain hedge fund strategies.

It is encouraging to see that using factors relevant to the hedge fund replication strategy resulted in clones that offered similar performance to the average hedge fund. The results also show that setting a higher benchmark for the clones by selecting the top performing funds continues to produce good replication performance for the clones across many strategies. The added benefits of lower fees, daily liquidity, and complete transparency make the clones appear as an attractive choice even when they slightly underperform their fund counterparts. With the view of the clones as investable products or alternatives to hedge funds, the choice in the clone construction technique depends on the desires of the investor, including clone replication performance, clone raw return, or clone risk-reward performance.

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SECTION

2. CONCLUSION

The results in the thesis show the importance of selecting factors in accordance to the economic characteristics of the underlying hedge fund when constructing replication products. The clones constructed from factors specific to each hedge fund offer good replication performance across several hedge fund categories for both fixed weight and rolling window clones when considering all funds. It was observed that these clones also continued to offer comparable performance to a higher benchmark of funds consisting of funds with higher Sharpe ratios and higher raw returns for many categories. This is a promising step forward towards the implementation of hedge fund clones, and should challenge the average hedge fund for investor capital.

There are a number of points to keep in mind before selecting and implementing hedge fund replication products within one's portfolio. First, expenses related to rebalancing within the clones, such as transaction costs and borrowing costs that are needed for the required leverage, can have a negative impact on the performance of the clones. Second, hedge funds are capable of deviating from their stated styles and more complicated models are needed to capture this style drift. Finally, hedge funds have no obligations to report their monthly performance and can stop doing so at anytime. Therefore, hedge fund databases often have missing returns. This fact, combined with the relatively short history of hedge funds, presents a challenge when developing models to create accurate clones.

Keeping these points in mind, future research should focus on testing the validity of these results over a longer time frame and across a larger number of hedge funds. Also, to explore the possibility that fixed weight and rolling window models need different factors within the same hedge fund strategy, another possibility that needs to be analyzed is whether hedge funds have different exposures during bull markets and bear markets. Hedge fund indexes can be constructed using the various performance criteria, such as using the funds with best risk-reward ratio or the best returns, with these new indexes then being used to construct clones with the aim to replicate the constructed index.

The research in this thesis establishes the importance of using factors relevant to the underlying hedge fund strategy in the replication process and offers investors the choice between clone replication performance, clone raw return, and clone risk-reward performance. The success of hedge fund replication products will rely on the ability of the clones to offer the benefits traditionally expected from hedge funds, such as offering protection and diversity in an investors' portfolio, while hopefully generating above average returns. It is an exciting time in the world of hedge fund replication and there is reason to be optimistic that hedge fund-like returns can be achieved without investing directly in more expensive hedge funds.

VITA

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